XXXV.—*The Process of Fecundation in the Vegetable Kingdom, and its relation to that in the Animal Kingdom.* By Dr. L. Radlkofer.

[Continued from p. 262.]

4. Mosses.

The opinion that the antheridia of Mosses constitute the male reproductive organs of these plants, is as old as the observation that they are matured and their contents discharged at the same epoch as that at which the archegonia are developed,—as old, in fact, as any minute investigation of the characters of Mosses. Micheli*, Dillenius†, Linnæus‡, and Haller§, generally compared the spores of the Mosses with the pollen-grains of the Phanerogamia, and therefore took the capsule for the male and the antheridia for the female organs; while Micheli, Schreber||, and others had proclaimed the paraphyses, Hill¶ the teeth of the peristome, Kölreuter** the calyptra, Schmidel†† the cells between the inner and outer walls of the capsule, Miller‡‡ the upper part of the columella inserted in the operculum, and O. F. Müller§§ (in the Jungermannieæ) the abortive archegonia—as male organs;—Hedwig||||, however, first observed the development of the young plants from the spores, detected the relation in time in which the perfect condition of the antheridia, first discovered by him in the majority of Mosses (to which, also, Schmidel¶¶ ascribed a fecundating office), stood to the archegonia, and in consequence of this pronounced decidedly for the above-mentioned view. This opinion remained predominant from that time; and while, in recent times, more definite evidence was, with right, required of the sexuality of the plants, yet, in the face of the continually multiplying observations of the sterility of diœcious Mosses in the absence of antheridium-bearing individuals, criticism could scarcely do more than cause Hedwig's opinion to be expressed with a little less determination. Still more lately, however, an analogy was sought to be established between the spores and

* Nova Gen. Plant. Flor. 1729, p. 108. pl. 59, H. J.

† Histor. Muscorum. Oxon. 1741.

‡ Syst. Natur. ed. 12. Holm. 1767, ii. p. 698.

§ Historia Stirpium. Bern. 1768.

|| J. Ch. D. Schreber, De Phasco Observationes. Lips. 1770, p. xix.

¶ History of Plants. London, 1751.

** Das entdeckte Geheimn. der Krypt. Karlsruhe, 1777, pp. 34, 133.

†† Dissert. de Buxbaumia. Erlang. 1758, § xxiv. p. 37.

‡‡ Illustration of the Sex. System of Linnæus. London, 1779, i. p. 104, pl. 103. figs. 10–13.

§§ Flor. Friedrichsdal. Argentor. 1767, p. 188, no. 378.

|||| Theoria Generat. et Fruct. Plant. Crypt. Petrop. 1784.

¶¶ Icones Plant. ed. 2. Erlang. 1793, i. p. 85. no. 4.

pollen-grains—not, however, in the same sense as by Linnæus—by Valentine* and Schleiden†, so long as the latter regarded the pollen-grain as the vegetable ovum.

The antheridia consist, in the Liverworts‡, of an ellipsoidal mass of small cubic cells, which are enclosed by a layer of larger cells containing chlorophyll; sometimes they are imbedded in the frondose stem (*Riccia, Pellia*), or on a special receptacle (*Marchantieæ*); sometimes they are borne on small cellular pedicels on the frond (*Fossombronia*), or on the axils of the leaves (leafy *Jungermannieæ*). In the Mosses§ their structure is the same, but their form is in general more cylindrical, their place at the end of the stem (of the shoot). In the interior of each of those cubic cells, which, when the antheridium is perfectly ripe, separate from their fellows and become absorbed, is formed, nearly filling it, a lenticular vesicle (daughter-cell?—see on this point Nägeli ||, who calls it a 'seminal utricle' = *samen-bläschen*), in which is developed a spirally-coiled spermatozoid¶. After the escape of the vesicle from the opened apex of the antheridium, each spermatozoid is set free, by rupture or solution of the vesicle, and moves about in the water by the help of two long cilia.

Schmidel**, to whom we are indebted for the knowledge of the antheridia of Liverworts, detected the motion of the discharged contents of the antheridia of *Fossombronia pusilla*, without clearly perceiving the spermatozoids themselves; the same was the case with Nees v. Esenbeck in respect to *Sphagnum capillifolium*††. The latter regarded the vesicles, set in motion by the still en-

* Trans. Linn. Soc. xvii. London, 1837.

† Grundz. wiss. Botanik.

‡ *Vide* on this point the excellent works of—

Nees v. Esenbeck, Naturgesch. d. europ. Lebermoose. Berlin, 1833.

G. W. Bischoff, Bemerk. üb. die Lebermoose. Nova Acta A. C. L. C. xvii. pt. 2. p. 924.

J. B. W. Lindenberg, Monogr. der Riccien. Nov. Act. A. C. L. C. xviii. pt. 1. p. 392.

C. M. Gottsche, Ueb. *Haplomitr. Hookeri.* Nova Acta, xx. pt. 1. p. 293.

Hofmeister, Vergleich. Untersuch. &c., höh. Krypt. Leips. 1851.

Thuret, Rech. sur les Anthéridies des Cryptog. Ann. des Sc. nat. 3 sér. xvi. (1851).

§ See W. P. Schimper, Rech. anat. et morpholog. sur les Mousses. Strasburg, 1848.

Thuret, *l. c.*

Hofmeister, *l. c.*, and Botan. Zeit. 1849, p. 793.

|| Zeitschr. f. wiss. Botanik, Heft 3 & 4. Zurich, 1846, p. 105.

¶ Schacht believes that he has certainly observed that the spiral filaments are produced from the nuclei of the cells, of which one exists in each of the daughter-cells formed in fours inside the antheridium-cells. *Vide* Pflanzenzelle. Berlin, 1852, pp. 107, 112; Ueb. Antherid. der Leberm. Bot. Zeit. 1852, p. 155.

** Icones Plant. ed. 2. Erlang. 1793, i. p. 85. no. 5. pl. 22. fig. 8.

†† Flora, 1822, B. i. p. 33. pl. 1.

closed spermatozoids, as Monads; the former observed the spermatic vesicles with the spermatozoids imperfectly extricated from them, and described them as actively-moving, stalked molecules, possessing a tail. Later observers, as Mirbel*, overlooked this motion. Unger† first distinctly observed the spermatozoa themselves, and called them *Spirillum bryozoon*. Decaisne and Thuret‡ observed their cilia. Hofmeister§, who, following Nägeli‖, traced the antheridia back to the first cell, could find only two cilia in *Pellia*. Schacht¶ did not see more than one anywhere.

The statements of Gottsche** and Schacht††, that the antheridia of some Liverworts have the envelope composed of a double layer of cells,—and those of Unger‡‡, Schleiden§§, and Schacht‖‖, that the whole of the spermatic vesicles are contained in one large cell whose wall lies immediately beneath the envelope,—are in contradiction to the observations of Hofmeister¶¶.

The archegonia, for a knowledge of whose whole course of development we are likewise indebted to Hofmeister, in their earliest stages exactly resemble the rudimentary antheridia. When fully developed, they consist of flask-shaped organs, mostly stationed at the ends of the shoots, and surrounded by special leaves (*perichætium*, Mosses), or cup-like envelopes (*calyx*, Liverworts); more rarely they are immersed in the flat stem (*Riccia*). The axial row of cells of each archegonium loses its horizontal walls by solution, so that they are converted into a canal, which leads below into an enlarged cell (central cell of the archegonium) lying in the expanded part, and at the epoch of puberty opens at the top by the separation of the uppermost layer of cells bounding it. According to Hofmeister***, the central cell of the archegonium contains a daughter-cell formed

* Compl. des Obs. sur *Marchantia*. Mém. de l'Instit. de France, xiii. p. 377. Paris, 1835.

† Ueb. Anthere v. *Sphagnum*. Flora, 1834, i. p. 145.—Neuer Beob. üb. die Moos-anthere, &c. Nova Acta A. C. L. C. xviii. pt. 2. p. 687.—Weitere Beob. üb. die Samenthierch. der Pflanzen. Ibid. p. 785 (Ann. des Sc. nat. 2 sér. xi. p. 257, 1839).

‡ Ann. des Sc. nat. 3 sér. iii. p. 14 (1845); xvi. pl. 10–14 (1851).

§ Vergleich. Untersuch. &c. Leipsic, 1851, p. 16.

‖ Zeitschr. f. wiss. Botanik, Heft i. p. 172. Zurich, 1844.

¶ Das Mikroskop, &c., 2nd ed. Berlin, 1855, p. 86.

** Nova Acta, xx. pt. 1. p. 294. pl. 16. fig. 8.

†† Pflanzenzelle, p. 109; Mikroskop, p. 83.

‡‡ Nova Acta, xviii. pt. 2. p. 689. pl. 53. fig. 1, *b*.

§§ Grundz. d. wiss. Botanik, 3rd ed. ii. pp. 67 & 80.

‖‖ Pflanzenzelle, p. 110.

¶¶ Vergleich. Unters. &c. Leips. 1851, pp. 43, 69; and Flora, 1855, p. 438.

*** Flora, 1854, p. 259.

round a secondary nucleus (the rudiment of the future capsule) before the time when the canal opens at the top. Pringsheim* states that he could not convince himself of the presence of this cell *before* fecundation.

The majority of the archegonia are arrested at this stage of development. In the rest, as Hofmeister has shown, and as Valentine† likewise had previously described, there originates from the last-mentioned free cell, by repeated division and the enlargement of the newly produced cells, a more or less fusiform cellular mass (formerly described as a 'nucleus,' and regarded as an integral part of the archegonium—and so even by Schacht‡), lying free in the simultaneously expanding cavity of the original central cell, its lower end penetrating, in its further growth, into the base of the archegonium, and becoming intimately connected with the surrounding structures through the products of solution of the cells which it here displaces. The archegonium being no longer capable of withstanding its continued vertical extension, becomes circularly torn at the bottom, and its upper fragment is carried up by the young capsule as the *calyptra*, while the remnant remains as the *vaginula*§. I need not further describe the development of the lower part of the cellular body into the *seta* (*pedunculus*), and of the upper into the *theca* (*capsula*), still less the formation of the spores through quaternary cell-division in mother-cells which are arranged in one or more layers. It is equally unnecessary to discuss here the analogies between this and the formation of pollen in the Phanerogamia‖. The spore-capsules of the *Marchantieæ* and of

* Pringsheim, Ueb. Befrucht. u. Keimung der Algen, &c. Monatsber. Berlin. Acad. 1855, p. 15.

† W. Valentine (Trans. Linn. Soc. of London, xvii. p. 466, read May 7th and June 18th, 1833) had already described a free cell at the bottom of the archegonium, and assures us that he had succeeded in dissecting it out *uninjured*. See also his figures, pl. 23. figs. 1–7, and the explanation, p. 482.—H. Philibert likewise detected a free cell ('*embryo-cell*') before fecundation in the central cell of the archegonium (which he called the 'embryo-sac') both in Mosses and Liverworts, and in the Ferns. Comptes Rendus, 1852, p. 851; Ann. Nat. Hist. 2nd ser. xi. p. 482 (1853).

‡ Bot. Zeitung, 1850, p. 459. pl. 6. figs. 1–4.

§ *Vide* Hofmeister, *l. c. supra*; and on the structure of the ripe capsule, Lantzius-Beninger, Nova Acta, xxii. pt. 1; and Schimper, Recherch. sur les Mousses, &c. Strasburg, 1848.

‖ See hereon—

V. Mohl, Ueb. Entw. d. Sporen von *Anthoceros lævis*. Verm. Schr. p. 84, and Einig. Bemerk. üb. d. Entw. u. Bau der Sporen der Crypt. Gewächse, *id. op.* p. 67.

Lantzius-Beninga, De Evolutione Sporid. in Capsul. Muscorum. Götting. 1844.

Schacht, Beitr. z. Entwick. d. Frucht u. Sporen v. *Anthoceros lævis*. Bot. Zeit. 1850, p. 457.

Riccia are distinguished merely by their lower portion not becoming developed into a pedicel.

Only *Anthoceros* possesses, according to Hofmeister and Schacht, a structure of the archegonia aberrant from that hitherto described. They do not appear here as organs isolated from the rest of the cellular tissue, a particular row of cells of the frondose stem, simply, becoming converted into the archegonial canal. The cell lying immediately beneath this row assumes the part of the central cell of an archegonium.

Hofmeister found inside the calyx of *Jungermannia bicuspidata* and *divaricata*, beside the just-opened archegonia, spermatozoids still in motion; motionless ones frequently in the mouth of the archegonial canal*, and, according to his most recent publication†, still moving ones which had penetrated a third of the distance down the archegonial canal in *Funaria hygrometrica*. A similar statement is made by Schimper in respect to *Sphagnum*‡.

The development of the young plant of Mosses from the spore was first observed by Hedwig; more recently, by Nees v. Esenbeck, Bischoff, and, above all, by Gottsche, W. Schimper and Hofmeister§. In the Mosses, it is not produced directly from the internal cell of the spore, but through the intermediation of a tissue of jointed confervoid filaments—*protonema* (*pro-embryo*, Hofmeister). According to Hofmeister, these filaments are not all of one kind, some appearing to correspond to stems, others to leaves. The former only are capable of development, by the division of their terminal cell by means of alternately inclined septa, into bud-rudiments, sometimes bearing leaves and root-fibrils, and thus of becoming the foundation of perfect Moss-plants. When they penetrate into the soil, they acquire oblique septa, and are destitute of chlorophyll, like the so-called roots of the Mosses; on the other hand, Nägeli || and Schimper have observed that the protonema-threads developed in the axils of leaves or from the cells of leaves (aërial roots of authors), and even the roots of Mosses, become green, form perpendicular cross-septa and produce buds, in situations where they are exposed to the light.

In regard to the Liverworts, Hofmeister's account of the development at least renders the universal occurrence of a pro-embryo doubtful¶. Gottsche's opinion is to the same effect**.

* Vergleich. Unters. pl. 8. figs. 49 (properly 79) & 61, pl. 9. fig. 2. pp. 37, 38.

† Flora, 1854, p. 259.

‡ Ann. des Sc. nat. 4 sér. i. p. 320 (1854).

§ *Op. cit. supra.*

|| Zeitschr. f. wiss. Botanik, Heft ii. p. 168. Zurich, 1845.

¶ See also Hofmeister, Ueb. die Stellung der Moose in Systeme. Flora, 1852, p. 6.

** Nova Acta A. C. L. C. xx. pt. 1. p. 386.

Bischoff thought he detected a pro-embryo in some species*. J. Groenland also regarded the cellular body produced by the spore in all the species he examined, which by no means passed gradually into the proper frond, as the pro-embryo (*protonema*)†.

5. Pteridoideæ (Ferns and their allies).

It would lead too far if I more than mentioned summarily the attempts of the older botanists to demonstrate in the Filices (in the widest sense) sexual organs, on the cooperation of which they believed the regular reproduction of all plants to depend—attempts which were taken up again with the more zeal, since Hedwig had made good so preponderating a probability of the existence of sexuality in the Mosses. While Linnæus and his predecessors thought that the spores of these plants generally must be identified with pollen, subsequent investigations as to their further development, their germination, the final result of which was known even by Morison and Stehelin, led, here as everywhere else, to their unconditional estimation as seeds, and consequently to that of the spore-capsules as female organs. The function of male organs of the flower has been attributed successively, in the true Ferns, to corpuscles (glandular hairs) occurring among the ramenta of the young petiole (Micheli‡)—upon these ramenta (Griffith§)—and on the points of the indusia (Schmidel‖); to the stomata (Gleichen¶); to the annulus of the capsules (Schmidel**); to groups of spiral-fibrous cells at the ends of the nerves of the leaves (Bernhardi); to the indusium (Kölreuter††); to the glandular hairs of the nerves of the pinnæ (Hedwig‡‡); to the contents of young spore-capsules with their spores (Gaertner and Mirbel); to the loose cells of the lenticels of Tree-ferns (V. Martius§§); to the glandular hairs occurring

* Bischoff, Bemerk. z. Entwick. der Lebermoose. Bot. Zeit. 1853, p. 113 (from observations made in 1828–9).

† Mém. sur la Germin. de quelques Hépatiques. Ann. des Sc. nat. 4 sér. i. p. 5 (1854).

‡ Tozzelius, in Append. ad Michelii Cat. pl. hort. Cæs. Florent. Florent. 1748, p. 135.

§ Posthumous Papers, Journal of Travels (teste A. Henfrey, Rep. Brit. Assoc. 1852, p. 107).

‖ Icon. Plant. ed. 2. Erlang. 1793, p. 48. pl. 13. figs. 6–9.

¶ Das Neueste aus dem Reiche der Pflanzen. Nuremb. 1764, p. 24. pl. 3. fig. 6. Abschn. ii. p. 30. pl. 24. fig. 9.

** Dissert. de *Buxbaumia*. Erlang. 1758, pp. 37, 38.

†† Das entdeckte Geheimn. der Kryptogamen. Karlsruhe, 1777, pp. 89, 135.

‡‡ Theoria Gener. et Fruct. Pl. Crypt. Petrop. 1784, p. 40.

§§ Denkschr. der Bot. Gesellsch. in Regensb. ii. p. 125 (teste V. Mohl, Verm. Schrift. p. 111).

on the pedicels of the spore-capsules of many Ferns (Presl*, Meyen†), &c. In the Equisetaceæ, Du Hamel‡, Hedwig§, and Vaucher‖ regarded as stamens the extremities of the elaters, upon which they had observed small granules; Kölreuter regarded the shields of the spore-fruits as stamens;—in the Lycopodiaceæ the membrane of the capsules¶. In the Rhizocarpeæ, most botanists regarded the small spores as male, and the large as female organs**.

Ferns (in the restricted sense).—Observations on the development of Ferns from their spores led Nägeli†† to the discovery of antheridia upon the lower face of the *prothallium* (*pro-embryo* of some authors), previously described (by Kaulfuss‡‡, Nees v. Esenbeck§§, &c.), and called the *pseudo-cotyledon*. Leszczyc-Suminski, Wigand, Thuret, V. Mercklin, Schacht, Hofmeister, and Henfrey have furnished contributions to the history of their development and the knowledge of their contents. In their origin and general structure they repeat the type of the antheridia of Mosses, and are usually elevated above the surface of the prothallium upon one or a few superimposed peduncular cells. Their envelope consists, according to Hofmeister‖‖, of a few large cells. These enclose a globular group of small cubic cells, whose walls are dissolved when the antheridia are ripe, and thus set free the vesicles (primary nuclei of the cubic cells?) contained in them, which have the spiral threads in their interior. The uppermost enveloping cell of the antheridia then tears in a stellate manner, the spermatic vesicles escape, and are likewise ruptured, letting out the spirally-wound spermatozoids, which are furnished with numerous cilia at the anterior, thicker extremity.

According to Wigand¶¶, the antheridia of different species, and often even those of one and the same prothallium, possess a different structure, in some cases consisting of a single cell.

* Tentamen Pteridographiæ. Prague, 1836, p. 15. pl. 11, A. B.

† Pflanzenphysiologie, iii. p. 199.

‡ Physique des Arbres. Paris, 1838.

§ *Op. supra cit.* p. 35.

‖ Monogr. des Prêles. Mém. de la Soc. d'Hist. nat. de Genève, i. pt. 2. pp. 350, 359 (Geneva, 1822).

¶ *Op. supra cit.* pp. 119, 135; pp. 73, 174.

** See the more complete bibliography in Mettenius, Beitr. z. Kenntn. der Rhizocarpen. Frankfurt, 1846.

†† Zeitschr. f. wiss. Botanik, i. Zurich, 1844, p. 168.

‡‡ G. Fr. Kaulfuss, Das Wesen der Farrenkräuter. Leipsic, 1827.

§§ Entwickl. der *Pteris serrulata.* Nova Act. A.C.L.C. xii. pt. 1. p. 157.

‖‖ Vergleich. Untersuch. Leipsic, 1839, p. 79 *et seq.*

¶¶ Alb. Wigand, Entw. der Farrenkräuter. Bot. Zeit. 1849, p. 17; and Botanisch. Untersuch. Brunswick, 1854, p. 44.

Leszczyc-Suminski* thus represents the antheridia of *Pteris serrulata.* Hofmeister observed such conditions only in the antheridia of the proliferous shoots of abortive prothallia†. Thuret‡ and Mercklin§ regarded the centre of the antheridium as an intercellular space; Schacht‖, in agreement with his views of the structure of the antheridia of Mosses, as a large cell, inside which the swarming-filament cells originated in fours in mother-cells. Henfrey¶ agrees with him in regard to the first point. The shape of the spermatozoids and the mode of arrangement of their cilia, first detected by Thuret and Suminski, are also stated by Wigand** to be very various.

The archegonia, the discovery of which we owe to Leszczyc-Suminski††, appear a little later, before the successive production of antheridia is at an end,—ordinarily upon the same, but in a few cases upon separate prothallia. They present themselves as shortly cylindrical, ellipsoidal organs projecting from the prothallium on the lower surface, and consist of four (8–10-jointed) rows of cells surrounding a central canal. The canal is formed either by the solution of the transverse walls of a fifth axial row of cells, or by the separation of the four rows at their common commissure. Both modes of formation occur in different archegonia of the same species, even of the same prothallium‡‡. According to Mettenius§§, the lower part of the canal is formed as an intercellular space above the central cell of the archegonium (called by Mettenius the germinal vesicle) before the longitudinal growth of the cylindrical neck of the archegonium is completed. This canal leads at the bottom to a cell, distinguished by its magnitude, seated at the base of the archegonium—the central cell of the archegonium. In this, as in the Mosses, before the opening of the canal externally, a free cell (germinal vesicle), a daughter-cell, is formed around a new secondary cell-nucleus‖‖, constituting the foundation of the new plant¶¶.

* Zur Entwickl. der Farrnkr. Berlin, 1848.

† Vergleich. Untersuch. &c. p. 84.

‡ Sur les Anthérid. des Fougères. Ann. des Sc. nat. 3 sér. xi. p. 5 (1849).

§ Beobacht. an dem Prothall. der Farrnkr. Petersburg, 1850.

‖ Pflanzenzelle. Berlin, 1852, p. 114; and Beiträge zur Entwickl. der Farrnkräuter, 'Linnæa,' xxii. p. 753 (1849).

¶ On the Dev. of Ferns from their Spores. Trans. Linn. Soc. London, xxi. p. 121 (read June 15 and Nov. 2 & 16, 1852).

** *Op. cit.* p. 46. †† *Op. cit.*

‡‡ The Ferns thus form, in reference to the construction of the archegonia, the connecting link between the Mosses on one side and the Rhizocarpeæ and Lycopodiaceæ on the other. Hofmeister, Vergl. Untersuch. p. 81. §§ Beitr. z. Botanik, Heft i. p. 18. Heidelberg, 1850.

‖‖ *Vide* Hofmeister, Ueb. Befrucht. der Farrnkr. 'Flora,' 1854, (Ann. Nat. Hist. 2 ser. xiv. p. 272.)

¶¶ As to the presence of this cell at the epoch before the archegonium

As a rule*, only one archegonium becomes further developed. The cell just described increases in size, until it fills the central cell, and is converted by repeated divisions into a multicellular, ellipsoidal body lying in the cavity of the archegonium, forming thus the rudiment of the new plant—the *primary, never-developed embryonal axis.* In the course of further growth, its point gradually acquires rather intimate adhesion to the cells of the base of the archegonium. Beneath the point, at the anterior side, turned towards the younger, cordately-notched border of the prothallium, sprouts out the *first frond,* soon breaking through the archegonium and curving upwards. Opposite this, from the side next the older part of the prothallium bearing the antheridia and radical hairs, arises the *first adventitious* root. The *main* (axial) *root,* the lower end of the ovate embryo, remains undeveloped. Between the first frond and the permanently undeveloped point of the embryo soon arises, as a little cellular papilla, the *secondary, developing axis* of the new plant, which continually throws out new fronds from beneath its apex.

On abortive prothallia, which under favourable circumstances continue to vegetate for a long time, new archegonia are successively developed, but of different shape, wanting the elongated neck; they were regarded by Suminski and Mercklin as younger stages of development of the archegonia. In addition to these, there occur numerous shoots bearing abundance of unicellular antheridia.

Leszczyc-Suminski and Mercklin† have observed the *entrance of the spermatozoa into the canal of the archegonia.* The account, long ago and generally refuted, given by the former, of the origin of the embryo from the end of a spermatozoid which had entered into the central cell of the archegonium—arising from confounding the coagulated protoplasm of the archegonial canal with a spermatozoid—requires no further notice. Even Mercklin modified Suminski's statements, saying that the spiral filaments which penetrated the archegonium "here dispose a cell (through dynamic or material action ?) to development under definite laws

becomes either abortive or further developed, Hofmeister, Wigand, Mercklin, and Suminski are agreed; Pringsheim, on the contrary, states that here, as in the Mosses, he could not detect it at this time as a cell (*vide op. cit.*). With him accords Henfrey, if we properly connect his comparison of the said structure with the germinal vesicles of the Phanerogamia (Linn. Trans. xxi. p. 125), and his opinion, subsequently to be mentioned, that these germinal vesicles possess no membrane before fecundation, but are mere masses of protoplasm.

* Exceptional cases were observed by Mercklin and Wigand (*vide op. cit. supra*).

† *Vide op. cit. supra,* and Mercklin, Offentl. Briefe an H. Schacht, 'Linnæa,' xxiii. p. 732.

of formation, whose product is the frond." Hofmeister has recently seen* *the spermatozoids penetrate through the attenuated and softened membrane of the central cell of the archegonium, into its interior, and then for a time move round the free part of the germinal vesicle.* The inner end of the canal of such archegonia appeared closed by the subsequent expansion of the surrounding cells,—the first sign of fecundation having taken place.

EQUISETACEÆ.—The so-called germination of the spores of the *Equiseta* had been long ago minutely investigated, especially by Agardh†, Vaucher‡, and Bischoff§, but it was only after the discovery of the antheridia of the Ferns had excited new conjectures, that the antheridia were observed in the irregularly lobed prothallium of the *Equiseta,* first by Thuret ||, and afterwards by Milde¶ and Hofmeister**. They occur upon the border of the prothallium, as conical, cellular papillæ, not definitely separated from the prothallium, but with their bases imbedded in it; the cells of their simple envelope are directly continuous with the upper layer of cells of the prothallium. The nucleus consists, in the young state, of small cubical cells, in which are formed spiral-thread-producing vesicles, in the same way as in the Ferns. When perfectly ripe, they open by the separation from each other of the upper cells of the envelope, which remain connected with the lower cells only by their inferior walls, and surround the orifice like a crown††. The spermatozoids are larger than those of the Ferns—in fact, are the largest hitherto met with in plants, and consist of a band-like body, wound like a corkscrew, furnished with numerous cilia at the anterior extremity. The posterior extremity, in contrast to that of all other known spermatozoids, is much spread out.

The emission of the spermatozoids from the spermatic vesicles is often imperfect, as occurs also in the Mosses and Ferns; the vesicle then remains hanging on the anterior or posterior extremity of the spermatozoid, and is carried along by it.

The first notice I find of the detection of a (dead) archegonium

* Flora, 1854, p. 257. (Ann. Nat. Hist. 2nd ser. xiv. p. 273.)

† Observ. sur la Germination des Prêles. Mém. du Muséum, Paris, ix. p. 283 (1822).

‡ Monogr. des Prêles. Mém. de la Soc. phys. &c. de Genève, i. pt. 2. p. 347 (1822). Mém. sur la Fructification des Prêles. Mém. du Muséum, Paris, x. p. 429 (1823).

§ Kryptog. Gewächs. Nuremberg, 1828.—Ueb. Entw. d. Equiseteen. Nova Acta L. C. N. C. xiv. pt. 2. p. 779 (1828).

|| Ann. des Sc. nat. 3 sér. xi. p. 10 (1849).

¶ Zur Entwickl. der Equiset. u. Rhizocarp. Nov. Act. xxiii. pt. 2. p. 630. De Sporarum Equiset. Germinat. Linnæa, xxiii. p. 558 (1850).

** Vergleich. Untersuch. &c. p. 100.

†† See Thuret's figure, Ann. des Sc. nat. 3 sér. xvi. pl. 15 (1851).

on the prothallium of the *Equiseta* is by Mettenius*. Hofmeister† and Milde‡ had figured rudiments of archegonia in their earlier essays; subsequently these two observers simultaneously discovered them in a developed condition on prothallia which, after various, often unsuccessful attempts, they had raised from the spores; Milde in *Equisetum Telmateia*§, Hofmeister‖ in *Equisetum arvense* (*pratense* and *variegatum*).

In the species hitherto observed the archegonia are ordinarily developed, and at a comparatively late period, on separate prothallia¶, not bearing antheridia at the same time, distinguished by more vigorous vegetation, or at least upon separate, later-formed shoots of the prothallium**. They originate at the border of the prothallium, but by the continued development of the mass of the prothallium under them, they are ultimately brought upon its upper surface. Their structure is essentially the same as in the Ferns; their course of development is as follows††:—A cell of the surface of the prothallium bulges outwards and divides into two superposed cells by forming a septum parallel to the surface of the prothallium. The lower cell of the two is the *central cell* of the archegonium; the upper cell is divided by two septa at right angles to each other, but perpendicular to the upper surface of the central cell, into four cells, which by repeated division by horizontal septa, form the cylindrical neck of the archegonium, consisting of four collateral rows of cells. The cells bordering on the central cell, dividing many times, form one or two epithelium-like layers of cells surrounding the central cell. The cells at the apex of the neck of the archegonium elongate more than the lower ones, and curve back, after the formation of the archegonial canal (by the separation of the four rows of cells at their common commissure), like the top of the stigma of a *Campanula*. In the very earliest stages of development of the archegonium, a free daughter-cell—the *germinal vesicle*—is formed round a secondary nucleus in the central cell‡‡. That part of

* Beiträg. zur Botanik, Heft 1. Heidelberg, 1850, p. 22.

† Vergleich. Untersuch. Leipsic, 1851, pl. 20. figs. 61, *a*, *b*, & 62.

‡ *Op. supra cit.* pl. 59. fig. 47, *a*.

§ Das Auftreten der Archegon. am Vork. von *Equiset. Telmateia*, Ehr. Flora, 1852, p. 497. (Aug. 28. From a private letter to Prof. Schleiden, accompanied by a drawing, dated June 20, 1852, I find that this discovery was made simultaneously with Hofmeister's.)—Zur Entwick. d. Equiseteen Bot. Zeitung, Aug. 6, 1852, p. 537.

‖ Ueb. Keimung der Equisetaceen. Flora, 1852 (June 7), p. 385.—Beitr. z. Kenntn. der Gefäss-Kryptog. Abhandl. Sächsisch. Gesellsch. der Wissensch. Leipsic, 1852, p. 168. pl. 17–19.

¶ B. Bischoff describes an exceptional case in *Eq. sylvaticum*, L. (Bemerk. z. Entwick. der Equiset. Bot. Zeit. 1853, p. 97.)

** *Vide* Milde, Nova Acta A. C. L. C. xxiv. pt. 1. pp. 68, 71 (1854).

†† *Vide* Hofmeister, *op. supra cit.*

‡‡ Milde was fortunate enough to press out this cell 'entire' from a

the contents of the central cell not consumed in nourishing the germinal vesicle, appears to be discharged into the canal of the archegonium.

Ordinarily, more than one archegonium is fecundated on the same prothallium. The earliest processes after fecundation has taken place, are so completely accordant with those in the Ferns, that their description may be passed over. Here, again, *the primary axis of the embryo remains undeveloped.* On one side of its apex shoots forth the *secondary axis* of the new plant, soon turning upward and penetrating through the prothallium; opposite to it, and breaking through the prothallium below, appears the first *adventitious root.*

RHIZOCARPEÆ.—To Nägeli* we owe the knowledge of the spermatozoids of these plants. They are developed as simple filaments in minute vesicles (nuclei?), which are contained, singly (*Pilularia*) or several together (*Salvinia*), inside small cells produced during the so-called germination of the *microspores*; this germination consisting of the bursting of the cuticle and the protrusion of the internal cell in the form of a tube about as long as the spore, inside of which those cells are formed, afterwards to be set free by its bursting. In *Salvinia* the microspores are agglutinated together inside their sporangium; they germinate without leaving it, their tubes breaking out through it†. From the isolated cells the spermatozoids themselves emerge at once, without any previous escape of their parent-vesicles from the spore-cell. In their motion and the arrangement of their cilia they exactly resemble the spermatozoids of the Polypodiaceæ‡.

The same inquirer opened the way to the correct comprehension of the *prothallium,* which emerges from the summit of the *megaspore,* composed of few cells, and remains in connexion with the spore to bear the *archegonia* there. Our insight into the import of this organ was completed by the investigations of Hofmeister§ and Mettenius‖.

The archegonia of *Pilularia* perfectly agree with those of the Equisetaceæ in the main points of structure. In this, as in the next genus, the prothallium bears only one archegonium.

In *Marsilea* there is a little difference, since not only the four

favourably ruptured archegonium. Nova Acta A. C. L. C. xxiv. pt. 1. p. 69 (1854).

* Fortpflanz. der Rhizocarpeen. Zeitschr. f. wiss. Bot. Heft iii. & iv. p. 188. Zurich, 1846.

† Milde, Beitr. z. Keim. v. *Salvinia* u. *Pilularia.* Nova Acta A. C. L. C. xxiii. pt. 2. p. 642. pl. 60.

‡ Hofmeister, Vergleich. Untersuch. p. 109.

§ *Op. supra cit.* p. 103; and Fruchtbild. u. Keim. der höher. Krypt. Bot. Zeit. 1849, p. 793.

‖ Beitr. z. Botanik, Heft i. p. 3.

cells originally covering the central cell, but also those lying beside them, undergo repeated division by cross-septa, parallel to the outer surface of the prothallium, where the neck of the archegonium appears immersed in the substance of the prothallium instead of projecting in a cylindrical form above it.

In *Salvinia,* finally, this neck of the archegonium is composed exclusively of these four covering-cells. The archegonial canal leading to the central cell is then a short intercellular passage formed by the separation of these cells at their common commissure. Two germinal vesicles are often formed in the central cell here*.

The transformation of the germinal vesicle into the embryo, and its subsequent development, follow essentially the same type as in the Equisetaceæ and the Ferns.

The statements of earlier observers, that when the microspores and megaspores are kept apart, the latter produce prothallia, but no young plants, are confirmed by Hofmeister†.

The *microspores* are formed inside spore-cases comparable with those of the Ferns, collectively enclosed, with the megaspores, in a common envelope, which constitutes the *fruit* (*receptaculum*) of the Rhizocarpeæ. Their *development* is according to the same type as that of the formation of pollen in the Phanerogamia, in special mother-cells arranged tetrahedrally inside a mother-cell. The *megaspore* is produced by the preponderating growth of a young spore of this kind, accompanied by the displacement of not merely the other young spores contained in the same mother-cell, but also of all the rest of the spores in the whole sporange (together with their enveloping mother-cells). In *Salvinia,* the microspores and megaspores are contained in separate receptacles.

The analogy of structure between the large spore of *Azolla* and that of *Salvinia,* as also between the microspores of the same genera, has been demonstrated by Mettenius‡.

Lycopodiaceæ.—A. *Selaginelleæ.*—The excellent researches of Mettenius§ and Hofmeister|| show us that the *small* and *large spores* of the *Selaginelleæ* behave exactly like the microspores and megaspores of the preceding groups, both in reference to their *mode of development* and their *import in the process of reproduction.*

As regards the first, it will suffice to observe, that the course of development of the *megaspore-capsule* (*Kugel-kapsel,* Hofm.) is the same as that of the *microspore-capsule* (*Staub-kapsel,* Hofm.),

* Flora, 1854, p. 257.

† Among them was P. Savi, Sulla *Salvinia natans,* &c. Biblioth. Italic. xx. (G. L. Duvernoy, De *Salvinia nat.* Dissert. Tübingen, 1825, p. 5).

‡ Linnæa, xx. (1847); Ann. des Sc. nat. 3 sér. ix. p. 116 (1848).

§ Beitr. z. Botanik, p. 7.

|| Vergleich. Untersuch. p. 118.

as far as the formation of the mother-cells of the spores. In the megaspore-capsule only one of these continues its development —to the formation of four special mother-cells, and spores, all of which here attain their full development. According to Hofmeister, the spore-capsule is not produced from the leaf upon which it afterwards appears implanted, as assumed by V. Mohl*, but arises from the cells of the stem just above the leaf.

Five months after sowing, Hofmeister saw small globular cells in the microspores, in which cells were developed spirally-coiled spermatozoids, moving slowly after they had emerged from the cells †.

Not until six weeks later occurs the *so-called germination of the megaspores,* the development of a prothallium bearing archegonia, so that fecundation could only be possible when later-sown microspores were present at this epoch. While the megaspore is still contained in its capsule, it exhibits at its upper part (under the point where it was originally in contact with the three sister-spores, at which place meet three ridges with longitudinal slits, corresponding to the commissural angles) a double layer of cells, of which it is not yet decided whether they are produced by free cell-formation in the manner of the endosperm-cells in the embryo-sac of the Coniferæ, or by cell-division. A few repetitions of the process of longitudinal and transverse cell-division convert this layer into the flat *prothallium.* At several points on this arise *archegonia* formed by the horizontal division of a cell bulging outwards, enlargement of the lower, new cell into the central cell, and the successive division of the upper into two tiers, each composed of four cells, the upper tier of which alone projects from the surface of the prothallium. The archegonial canal and the germinal vesicle are formed as in the Rhizocarpeæ. The free space in the cavity of the spore situated below the prothallium becomes gradually filled up with cellular tissue which grows from above downwards.

The first step in the *formation of the embryo* is the horizontal division of the germinal vesicle. Ordinarily this is repeated a number of times, with simultaneous longitudinal extension of the newly-formed cells; in this way is formed a pro-embryonal cord of cells (*suspensor*) which penetrates downwards into the cellular tissue filling the megaspore, and here first gives birth to the body of the *embryo,* by the division of its end-cell by alternately-inclined septa. The secondary axis is not produced from the apical cell of the embryonal mass, but from one at the side, quickly assuming an ascending direction, breaking through the

* H. Von Mohl, Vermischte Schriften, p. 106.

† [We have found the spermatozoids developed, but not yet moving, after a much shorter interval than this.—A. H.]

prothallium above and soon displaying leaves; the first adventitious root appears opposite to it. The end of the primary axis expands in the internal cavity of the spore, displacing the cellular tissue existing there. It is rare for more than one embryo to be formed on a prothallium.

B. *Isoëteæ.*—The reproduction of *Isoëtes* is the same in all essential points as in *Selaginella*. The *spermatozoids* are developed in lenticular vesicles, which are produced singly or two together in small cells formed from the contents of the *microspores* (in their so-called germination). The spermatozoids are filiform, with the anterior end thicker and ciliated, the posterior attenuated; the movement is slow compared with that in the Ferns. Mettenius observed this first*.

Hofmeister† gives a complete history of the stages of *development of the embryo*. It agrees in its essentials with that of *Selaginella*, but the suspensor is wanting. Rarely more than one embryo is developed on the same prothallium. Hofmeister‡ believes that he has often seen the remains of spermatozoids which had ceased to move, lying in the archegonial canal.

C. *Lycopodieæ.*—There still exists here an essential gap in our knowledge of the reproduction of the higher Cryptogamia. The sowing of the spores of this group has never been attended with any result hitherto, however frequent or varied the attempts may have been. Since they only bear one kind of spore, it may be conjectured that this produces in germination a prothallium bearing both antheridia and archegonia.

6. Phanerogamia.

In the Phanerogamia Meyen§ attempted a comparison between the granules of the fovilla (in part starch-granules, as in the Onagraceæ) which exhibit molecular motion, and spermatozoids, calling these granules "spermatic molecules." Grisebach‖ imagined that he found in the winter-buds of *Rhamnus infectoria* and other plants an apparatus analogous to the antheridia of the Mosses and Ferns (to which at the same time he denied any sexual import), believing that he found in them long-tailed corpuscles ("*Phytozoa*") either enclosed in a cell or swarming about free. Itzigsohn did not hesitate to assert that these phytozoa were the true spermatozoids of the Phanerogamia¶. A production of cellules in the pollen-tubes of the Coniferæ, similar to

* Beitr. z. Botanik, p. 16.

† Beitr. z. Kenntn. der Gefässkryptog. Abhandl. Sächsisch. Gesellsch. der Wissenschaft. iv. p. 123. Leipsic, 1852. See here also for the other bibliography on *Isoëtes*.

‡ *Op. cit.* p. 131.

§ Pflanzenphysiologie, iii. p. 192.

‖ Botan. Zeitung, 1844, p. 661.

¶ Bot. Zeit. 1849, p. 560.

what occurs in the tubes of the microspores, led Hofmeister to the conjecture that spermatic filaments might also be produced there*; but his own later researches, and those of Schacht†, have not confirmed this supposition.

Coniferæ and Cycadeæ (Gymnospermia).—In the Coniferæ the investigation of the *formation of the embryo* has not arrived at satisfactory conclusions in all points‡. But there exists evidence to produce overwhelming probability that it originates from a cell—*a germinal vesicle*,—with which the pollen-tube enters into as intimate contact as in the rest of the Phanerogamia. But the process of fecundation in Coniferæ deviates strikingly in two points.

The first deviation is in the *organization of the ovule*. The embryo-sac here becomes filled-up with endosperm, by cell-formation around free nuclei and subsequent cell-division, before the complete penetration of the pollen-tube through the nucleus (which is clothed by a single integument). Certain of these endosperm-cells (belonging to the second stratum, counting down from the micropyle) expand, displacing the neighbouring tissue, forming *secondary embryo-sacs* (*corpuscula*, R. Br.), and subsequently, as 5–8 longish sacs, either lie immediately side by side (Cupressineæ) or remain separated by layers of unenlarged endosperm-cells. That cell of the outermost layer of endosperm-cells which covers the summit of each *corpusculum*, is converted by crossing perpendicular walls into a rosette of four cells, between which the pollen-tube, after breaking through the softened membrane of the (primary) embryo-sac, subsequently penetrates, bulging out, either simply to apply itself upon the outside of the *corpusculum*, or, by the absorption of the apex, to advance some distance into the interior.

About this time the corpusculum becomes filled up with delicate cells (some of which already contain four daughter-cells), swimming free, one of which immediately begins to enlarge, and is subsequently found at the end of the corpusculum turned

* Vergleich. Untersuch. p. 132 (1851).

† 'Flora,' 1854, p. 529.

‡ *Vide*: Hofmeister, Vergleich. Unters. &c. Leipsic, 1851, p. 126; Ueb. Befrucht. der Coniferen. Flora, 1854, p. 529. (Ann. Nat. Hist. 2 ser. xiv. p. 429.)

Schacht, Pflanzenzelle, p. 417 (1852); Beitr. z. Anat. u. Phys. der Gewächs. Berlin, 1854, pp. 287, 324; Das Mikroskop. Berlin, 1855, p. 148.

Géléznoff, Ann. des Sc. nat. 3 sér. xiv. p. 188 (1850).

Pineau, Ann. des Sc. nat. 3 sér. xi. p. 83 (1849).

Gottsche, Botanische Zeitung, 1845, pp. 378, 507.

Mirbel et Spach, Ann. des Sc. nat. 2 sér. xx. p. 257 (1843).

Rob. Brown, Ann. des Sc. nat. 2 sér. xx. p. 193 (1843); Ann. Nat. Hist. xiii. p. 368 (read at the meeting of the British Association at Edinburgh in August 1834).

away from the micropyle, where it first of all becomes divided by a cross-septum. Sometimes in both daughter-cells, sometimes in one only, there occurs a division by two vertical septa standing at right angles, forming the so-called lower cell-rosette, the *pro-embryo* (Hofmeister). After further cross-division once or several times repeated (and longitudinal division in some Coniferæ), the pro-embryo comes to consist of a few (3–4) superposed stories, each of 4–6 cells, the second or first of which (counting away from the micropyle) elongates greatly, breaks through the base of the *corpusculum,* and penetrates into the disintegrated endosperm, pushing onward the lower tiers of cells before it.

In the further behaviour of this *pro-embryo,* usually composed of four strings of cells, lies the second of the deviations indicated above; to wit, the individual strings of cells of which it is composed separate from each other gradually, from below upwards (in *Taxus* only imperfectly), and the end-cell of each string produces a rudimentary embryo of some size; but only one of all those contained in the ovule proceeds further in its development, all the rest becoming abortive. Some observers, especially Géléznoff, question the subdivision of the pro-embryo into single suspensors*.

So far as existing researches can show, the Cycadeæ agree with the Coniferæ in the organization of the ovule and the formation of the embryo.

Monocotyledones and Dicotyledones (Phanerogamia in the restricted sense).—In these plants, one (rarely more) of the two or more cells lying in the apex of the embryo-sac—the *germinal vesicles,*—is, through the influence of the *pollen-tube,* which ordinarily applies itself upon the outside of the embryo-sac, more rarely breaks through it, and allows a part of its contents to exude, enabled, by elongation and one or several times repeated cross-division, to change into a one- or many-celled *pro-embryo,* the *end-cell* of which, by repeated division in different directions, produces the embryo-mass, the *embryonal globule.* This constitutes the rudiment of the *first, developing axis* of the new plant, the lower end of which, turned toward the micropyle, becomes the *root,* while, by the sprouting of the first leaves below its point, the upper end becomes the *terminal bud.*

For the literature and the evidence of the statements made in the text, I refer the reader to my recently published memoir 'Die Befruchtung der Kryptogamen,' Leipsic, 1856. To the literature cited in the historical part of that essay—in which it was only intended to touch upon what was of especial importance for the deve-

* Gottsche, Botan. Zeitung, 1845, p. 378 *et seq.*

lopment and present state of the question—I here add what I have learnt since from new works or from such as I had not then access to. For acquaintance with part of these I am indebted to Dr. Caspary. [The older literature here alluded to will be found for the most part included in the list of works appended to a Report by the translator on this subject, printed in the 'Annals,' 2nd ser. ix. p. 458.—A.H.]

An essay of Mirbel and Spach on *Zea Mays* ('Notes pour servir à l'histoire de l'Embryogénie végétale.' Ann. des Sc. nat. 2 sér. xi. p. 200, 1839; and 'Rectification d'un erreur,' &c., *id. op.* pp. 381, 382), is very far from hitting the decisive points.

Wilson's Researches on *Tropæolum majus* (Hooker's London Journal of Botany, ii. p. 623, 1843) do not go back to the epoch of the actual origin of the embryo.

Trécul ('Recherches sur *Nuphar lutea*.' Ann. des Sc. nat. 3 sér. iv. p. 328, 1845), according to his description, saw the pollen-tube in the micropyle canal, but regarded it as a "coagulated stream of fovilla," and he left it undecided whether the embryo seen in connexion with this "proceeded from the fovilla," or whether "the ovule also contributed a few granules" to its formation.

Dickie (Ann. Nat. Hist. ser. 1. xvii. p. 5, 1846, & ser. 2. i. p. 260, 1848) wandered from the right path. He, like Brongniart previously, took the end of the pollen-tube projecting from the micropyle for a process belonging to the nucleus (*Narthecium*) or the embryo-sac (*Euphrasia*), ending blindly outside (*ovule-tube*); the suspensor he thought was a continuation of this, and the point of the embryo-sac perforated; and he did not explain the connexion of the embryonal body with the end of the suspensor. According to his own view, he could not find the pollen-tube. Independently of these observations, his reasonings inclined to Schleiden's theory.

Gasparini (Ann. des Sc. nat. 3 sér. xi. p. 365, 1849), continuing his earlier publications, gave some very imperfect researches, deviating far from the facts, on the supposed formation of an embryo without the influence of the pollen, in Figs.

Cobbold ('Embryology of *Orchis, Gesneria*,' &c. Ann. Nat. Hist. ser. 2. x. p. 238. London, 1852; written in the summer of 1849) found in the embryo-sac before fecundation "one or more cytoblasts or embryonal vesicles," and believed that the embryo was formed either through the metamorphosis of one of these pre-existing "germinal or embryonal vesicles," under the dynamic influence of the fovilla, or, as appeared to him more probable, through the union of the contents of the pollen-tube with those of a germinal vesicle, which process he compared with the conjugation of the Algæ.

A. Henfrey ('*Orchis Morio*,' Linnæan Trans. xxi. p. 7. Read April 3, 1849) found ordinarily three germinal vesicles in the unfecundated embryo-sac; usually one, more rarely two of them were converted into embryos after fecundation by the pollen-tubes, which mostly travelled down a little distance on the side of the embryo-sac. His researches are accompanied by more detailed drawings than those of his predecessors in the examination of the same plant.

Sanderson ('*Hippuris vulgaris*,' Ann. Nat. Hist. ser. 2. v. p. 259,

1850) detected the germinal vesicle long before the bursting of the anthers, but only a single one. From this, after fecundation, he saw produced the suspensor and embryo.

H. Crüger ('Befrucht. bei den Orangen,' Bot. Zeit. 1851, p. 57) placed himself decidedly in opposition to Schleiden. His observations, however, were by no means complete; in particular, he did not detect in the unfecundated embryo-sac the germinal vesicles, of whose presence recent researches leave me in no doubt.

W. Hofmeister, in his memoir on *Zostera* (Bot. Zeit. 1852, p. 121, and Taylor's Scientific Memoirs, ser. 2. Nat. Hist. i. p. 239, 1853) adds to his numerous earlier researches a new history of development of the embryo, agreeing perfectly with his former account.

Postscript.—I make use of this opportunity to report on certain memoirs which, either more recent or of the same date as my own, have come into my hands since that was printed.

Schacht has published new researches 'On the Origin of the Embryo in *Tropæolum majus*' (Bot. Zeit. 1855, p. 641; Ann. des Sc. nat. 4 sér. iv.). He here detected the germinal vesicles in the unfecundated embryo-sac, but was of opinion that they disappeared again at the time when the pollen-tube entered the micropyle. He regarded the fecundated germinal vesicle, which he detected at a subsequent period, as a totally different structure from the first—namely, as the immediate prolongation of the pollen-tube.

Th. Deecke ('Entwickl. der Embryo der *Pedicularis sylvatica*,' Bot. Zeitung, 1855, p. 657; Ann. des Sc. nat. 4 sér. iv.) endeavoured to answer Hofmeister's objections to the interpretation given by himself and Schacht to his much-discussed preparation, and to strengthen his reasoning with the results of new investigations. I was indebted to the kindness of Th. Deecke for an opportunity of examining this preparation, and of acquiring a positive conviction as to the condition of the anterior end of the embryo-sac. I perceived not merely the two lines which Schacht has drawn as running away from the points of contact of the lateral boundary-lines of the embryo-sac and suspensor, and uniting below in an angle projecting downwards,—but also two others, which (as nearly as I can describe their positions) passed from the same points, each running about parallel to the lines drawn by Schacht on the *other* side, thence uniting at angles projecting upwards. These two lines, therefore, with the two drawn by Schacht, bounded an almost rhomboidal hole, which, from the condition of its edges, was doubtless artificial; one section of this (I do not recollect exactly whether the lower (figured) or upper one) being over, the other under the suspensor which had been drawn forward out of it.

With regard to Th. Deecke's newer preparations, on which pl. 10 is based, several of which also he was kind enough to show me, what I observed agrees no better with his drawings; for example, in the preparation drawn in fig. 6, I saw, in the space which exists in the drawing between the end of the suspensor (*t, p*) and what is represented as the introverted membrane of the embryo-sac, a germinal vesicle which had remained unfecundated; and in this, as well as in the suspensor, the characteristic surface of attachment against the internal wall of the embryo-sac.

In the 'Botanische Zeitung,' 1856, p. 121 (*Stachys sylvatica*), the same author publishes his latest researches. He has overlooked the germinal vesicles in the unfecundated embryo-sac. In the impregnated sac he never found but one; this he regarded as the pollen-tube, which he supposed to have penetrated into the embryo-sac. The point of attachment of the germinal vesicle to the embryo-sac was looked upon by him as a hole made by the pollen-tube.

Tulasne published first in the 'Comptes Rendus' (1855, No. 12. p. 790) a short report of the results of his later embryological studies, which have since appeared in full (Ann. des Sc. nat. 4 sér. iv. p. 65). So far as relates to the *fecundated* embryo-sac, they agree perfectly with our observations, and especially contain many proofs of the peculiar circumstance that the end of the pollen-tube often lies at a considerable distance from the point of attachment of the fecundated germinal vesicle to the outside of the embryo-sac. *On the other hand, Tulasne in these cases, again, has been unable to detect the germinal vesicles in the unfecundated embryo-sac.* Moreover, we miss frequently in his figures, and indeed in all the very recently fecundated embryo-sacs, any representation of the abortive germinal vesicles or their remains.

Tulasne's (erroneous) view of the act of fecundation has consequently undergone no alteration. The fact that (at the end of his essay) he considers it illogical to perceive the germinal vesicle in the unfertilized embryo-sac, cannot alter the fact of our having seen it.

A. Henfrey read before the Linnæan Society of London, March 4, 1856, a paper 'On the Development of the Ovule of *Santalum album*, with some remarks on the Phænomena of Impregnation in Plants generally,' the essential contents of which are reported in the Annals of Nat. Hist. ser. 2. xvii. p. 438 (published in Linn. Trans. vol. xxii. p. 69). He thinks that Griffith was decidedly in error on the point that the pollen-tube penetrated into the embryo-sac. The *unfecundated germinal vesicles detected in the embryo-sac* are stated by him to be devoid of a bounding cell-membrane, and he regards them as *mere masses of protoplasm* (pre-existing protoplasmic globules). He thinks that a similar relation is set up between the embryo-sac and the end of the pollen-tube, to that existing in the *conjugation of the Algæ.* Soon after the pollen-tube has become adherent to the point of the embryo-sac, the pre-existing protoplasmic globule—the 'germ-globule'—acquires a cell-membrane and becomes an *actual cell,* the *germinal vesicle,* from which is produced the suspensor.

I must abstain from any close discussion of Henfrey's observations until the entire memoir, with the drawings, is published, since I cannot until then contrast and compare what I saw in the preparation kindly shown me by Prof. Henfrey, with his own views derived from them. But I cannot help making a few remarks on the conclusions he has drawn.

My last-year's observations on various plants, and some which I have just completed on the unfecundated embryo-sac of *Viscum*, have taught me that the germinal vesicle by no means possesses so firm a cell-membrane as we are accustomed to see in completely-developed vegetable tissues; that it has sufficient solidity to retain its original oval form for a few moments when the section passing through, halves both embryo-sac and germinal vesicle; but very soon, directly the contents of the latter begin to coagulate under the influence of water, it shrivels up, follows the contracting contents, and can no longer be perceived as distinct from them. In other words, the coagulating cell-contents do not retract from the cell-wall, but remain constantly in intimate contact with it, the cell-wall coagulating equally with the contents. But that we have not here to do with a mere primordial utricle, with a *naked* cell, is shown by the following conditions:—If we take a portion of the embryo-sac of *Viscum album* consisting of about $\frac{1}{6}$th of its length, and turn this inside out, so that the germinal vesicles lie outside and are seen free, with no membranous portion of the embryo-sac lying over or under them to obscure the view,—and then carefully tear them with a needle, supposing this has not already happened in the previous manipulation,—*their membrane remains as an extremely delicate, ragged, and wrinkled pellicle* adhering to the everted inner surface of the embryo-sac. It is of unequal thickness—thicker at the base of the germinal vesicle, thinner at its apex. At the exact place where it passes off, free (as side-wall), from the basilar surface of the germinal vesicle, its surface of attachment to the embryo-sac, its optical section appears as a broad line with a double boundary, under a power of 160 diameters. Towards the apex of the germinal vesicle (turned away from the top of the embryo-sac) the membrane becomes thinner and thinner, until, at the very top, it is, in its earlier stages, a scarcely consolidated pellicle. *If the germinal vesicle had not a proper membrane*, of appreciable thickness at least at the base, the boundary-line of its surface of attachment to the embryo-sac could not present itself as *double*, which is the case here in *Viscum*, even under a low magnifying power. Henfrey's observations were made on flowers which had been long preserved in spirit: the germinal vesicles must here naturally have been contracted, and could no longer present a distinct cell-membrane. I shall discuss in the sequel Henfrey's view as to the occurrence of conjugation between the embryo-sac and the pollen-tube.

London, June 8, 1856.

[*Note by Translator.*—The remarks in the preceding paragraphs are by no means convincing. It is our universal experience of nascent cells, that the cellulose membrane, be it ever so thin, does not contract on the contents; on the contrary, it is always first somewhat expanded through endosmose, and *leaves* the contents, afterwards shrinking again (evenly), which is admissible by its elasticity; by that time, however, the contents have shrunk up and coagulated, so that they lie free permanently in the cavity of the cell.—Since the above notices were written, Schacht has published a paper on *Gladiolus Segetum* (Ber. Berl. Acad. May 22, 1856), in which he takes up our view entirely, from independent observation, made in ignorance of our researches. A notice of his results appeared in the Annals, ser. 2. xviii. p. 217, 1856. In a still more recent essay by Hofmeister (Jahrb. d. wiss. Botanik, Heft i. Berlin, 1856), the existence of a cellulose membrane on the germinal vesicle before fecundation, is said to be usual, but liable to exception.—A. H.]

[To be continued.]

XXXVI.—*On the Presence of Motile Organs, and the Power of Locomotion, in Foraminifera.* By P. H. Gosse, F.R.S.

In a valuable paper by Mr. Macdonald "On Deep Soundings in the Pacific," which was published in the 'Annals of Nat. Hist.' for October last, there occurs the following passage:—"With all our opportunities of observing living Foraminifera in the South-western Pacific, where they abound in the most diversified forms, we have never been able to discover their branched 'pseudopodia,' so called, or the slightest evidence of the crawling movement which they are reputed to exhibit; while we can vouch for the actual fixity of some."

I have read this passage over and over, and cannot come to any other conclusion than that, as the language is unlimited, it is intended that the doubts should apply to the whole class of Foraminifera. As the opinions of so excellent a zoologist will have deserved weight, though founded on evidence which is merely negative, it may not be amiss to furnish some positive testimony on the opposite side—testimony which I should otherwise have thought perfectly superfluous. For, on turning to the works of one of our most eminent physiologists, Dr. Carpenter, who has devoted much careful attention to these minute animals, I find him (in his treatise "On the Microscope," for instance, p. 503 *et seq.*) recognizing, without any doubt, the existence of pseudopodia; and he reproduces two beautiful figures, after Schultze, of the genera *Gromia* and *Rosalina*, taken from the life, in which these organs are seen extended in copious profusion. He does not, indeed, allude to their power of changing place; but to this fact, as well as to the existence of pseudopodia, I can add my own testimony.

In the spring of 1855, at Weymouth, I obtained, chiefly in the minute tufted Algæ, such as *Corallina, Polysiphonia,* and *Ceramium,* a good many specimens of the pretty little *Polystomella crispa.* These were always found, a few hours after the weed had been deposited in my vases, adhering to the glass, with the pseudopodia extended in opposite directions, just as